H. D. Savey

Interventional Radiology

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Christos A. Athanasoulis, M.D.
Head, Vascular Radiology,
Massachusetts General Hospital;
Professor of Radiology,
Harvard Medical School

Richard C. Pfister, M.D.
Head, Genitourinary Radiology,
Massachusetts General Hospital;
Associate Professor of Radiology,
Harvard Medical School

Reginald E. Greene, M.D.
Head, Chest Radiology,
Massachusetts General Hospital;
Associate Professor of Radiology,
Harvard Medical School

Glenn H. Roberson, M.D.
Radiologist-in-Chief,
Albany Medical Center Hospital;
Professor and Chairman,
Department of Radiology,
Albany Medical College;
Former Head, Neuroradiology,
Massachusetts General Hospital

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FOREWORD

The subject of interventional radiology could not have been discussed two decades ago because the concept was not yet born. The involvement of radiologists in therapeutic procedures had been limited to radiation therapy until practical considerations resulted in a rather clear-cut separation between the modalities of diagnostic and therapeutic radiology.

In the last 25 years, there has been a spectacular growth in the application of so-called "invasive diagnostic procedures" involving the use of intravenous injections of various substances, mostly contrast material; the intraarterial administration of contrast agents injected via needles and catheters; or the insufflation of air into the tissues or body cavities. The concept of using radiographs to guide the needle, probe, or catheter into a given area goes back 50 years. With few exceptions, these guided procedures were performed for diagnostic purposes. Expanded application of this idea could not take place until the development of the fluoroscopic image amplifier in the early 1950's eliminated the need for dark adaptation and allowed the operator to work in a lighted room.

From time to time, surgeons have utilized radiologic control to ascertain the position of a needle, particularly in the puncture of certain hollow viscera or of a cystic lesion. Although this could be considered an example of interventional radiology (i.e., the use of x-rays to guide or carry out therapeutic measures), in reality, interventional radiology was born after catheter techniques, particularly intraarterial catheterization, had reached a certain level of sophistication. Although the intraarterial insertion of catheters via the cutdown method had been in use for a number of years, this required a surgical intervention, with incision of the skin and arterial wall and the use of arterial sutures to be tightened when the catheter was removed. A revolutionary change occurred with the introduction of the Seldinger technique (1953), by which arterial catheterization could be accomplished percutaneously.

Undoubtedly the concept of interventional radiology was brought into focus because of the enormous growth and popularity of these intravascular catheterization procedures; however, other procedures also merit our attention. Interventions involving the chest, biliary tree, genitourinary system, retroperitoneal tissues, and skeleton, which do not usually involve vascular catheterization, are gaining importance. Some are clearly therapeutic procedures, such as drainage of an intraabdominal abscess, insertion of a temporary or semipermanent internal biliary drainage tube, or percutaneous nephrostomy to relieve ureteral obstruction, while others are primarily diagnostic, such as percutaneous needle biopsies of lung and bone.

What is interventional radiology? Can the term be applied only to therapeutic procedures or to certain diagnostic procedures as well (i.e., needle biopsies), provided that these can be performed only under radiologic guidance by a specially trained individual, usually a radiologist? Prior to the decade of the 1950's, radiologists adopted a passive attitude in their participation in patient care. To be sure, their opinions were based on observations made either from films or from fluoroscopic examinations, but the radiologist did not become involved in altering the patient's status or in manipulating the organ under scrutiny in order to elicit information that could be used for diagnosis. In my view, the latter can also be considered interventional radiology even though its purpose is diagnostic rather than therapeutic. Intravenous administration of a contrast agent for urography or oral administration of barium for an upper gastrointestinal examination may not be viewed as interventional radiology, since an effort is not being made to alter the physiologic status of the organ under examination. However, the administration of glucagon to relax the colon in order to differentiate organic narrowing from a spastic condition may be viewed as an example of interventional radiology. Perhaps the earliest

PREFACE

In the context of this textbook, radiologic interventions are defined as procedures that offer a diagnostic and/or therapeutic alternative to surgery. Since interventional procedures rely on sophisticated imaging and localization techniques, they must be applied by radiologists and other physicians with significant radiologic expertise. Our aim has been to describe, in a concise manner, the state of the art of interventional radiology. For didactic purposes and for easy access, the material has been divided on the basis of anatomic structures into six major sections: Cardiovascular System, Genitourinary Tract, Abdomen, Chest, Central Nervous System, and Bones and Soft Tissues. There are also sections on the use of these techniques in children and a look at the discipline in perspective.

The most notable aspects of interventional techniques in radiology are the unique series of events that led to their development and their substantial impact on patient care. Interventional techniques in the chest, vascular, and abdominal areas developed in very different ways.

The improvements in and popularization of chest biopsy techniques are directly related to the development in the 1960's of high-grade image intensification and sophisticated cytologic techniques. Previously, percutaneous needle aspiration biopsy had been performed only sporadically. The modern image intensifier allowed the radiologist to perform biopsy procedures in a lighted room, and the cytologic methods permitted sophisticated cancer diagnosis even when specimens were small. Dahlgren and Nordenström's pioneering efforts using percutaneous biopsy and the publication of their results led to more widespread use of this technique.

In contrast to the evolution of percutaneous chest biopsy was the development of therapeutic angiography. In the vascular area, imaging techniques had become far advanced long before embolization and other transluminal techniques were developed. Intraarterial infusion of vasoactive substances to control hemorrhage became possible after the radiographic demonstration of experimental gastrointestinal bleeding by Rastalli in 1959 and the subsequent demonstration of gastrointestinal bleeding sites in man by Nusbaum and Baum. Pharmacologic control of gastrointestinal bleeding from portal hypertension and other causes received great impetus with further work by these investigators in 1969. Later, transcatheter embolization techniques made possible the treatment of arteriovenous malformations and other bleeding lesions throughout the body, including those of the central nervous system. New catheters were designed such as those of Dotter and Judkins in 1964 for transluminal treatment of arteriosclerotic obstructions, and the evolution of balloon dilatation catheters by Grüntzig in 1974 broadened the application of transluminal angioplasty.

In the area of genitourinary radiology, percutaneous puncture techniques also depended on the availability of high-quality image intensification and modern cytologic methods. However, the use of percutaneous drainage and renal stone dissolution and retrieval was enhanced by the modification of catheters and needles. More recently, the introduction of ultrasound and computed tomography has greatly expanded the potential for accurate localization of lesions amenable to percutaneous biopsy and/or drainage.

Although the paths of development in the various subspecialties of interventional radiology have differed, the combined impact of these techniques on patient care has been substantial. Interventional radiology has altered clinical modes of practice. Biopsy techniques have been used successfully to identify specific tumors and infections so that appropriate treatment can be started without the need to carry out open surgical procedures. Treatment of bleeding and other vascular conditions with percutaneous transvascular techniques have made it possible to avoid surgery in selected patients.

example of interventional radiology was the administration of a fatty meal following the initial filming during cholecystography in order to provoke contraction of the gallbladder. Many of these procedures, however, are not discussed in this text lest the impact of its message be diluted.

A fundamental question still to be considered is who should perform these procedures and how much training is required? Some techniques are relatively simple and straightforward (e.g., needle biopsy of a superficially placed bone lesion); others must be viewed as complicated surgical procedures requiring of the operator considerable judgment and experience both in diagnosis and in the manipulative techniques necessary for their successful completion. Obviously, in the majority of institutions, the trained and interested radiologist is the best choice, but it must be remembered that these "interventions" involve various organ systems requiring the participation of subspecialists. This is the case in the Department of Radiology at the Massachusetts General Hospital, where organ-oriented subdivisions exist and a number of radiology subspecialists are involved. Consultation with physicians or surgeons caring for a patient is essential, for often the interventional radiologic procedure is only one aspect of the total patient management strategy and is sometimes preliminary to a more definitive procedure.

Three types of applications of interventional radiology are discussed in the various chapters: (1) To provide a therapeutic alternative or to assist in the therapeutic management of certain conditions; (2) to obtain a tissue diagnosis through techniques requiring radiologic guidance; and (3) to obtain physiologic data that will assist in the diagnosis of a disease process and in the management of the individual patient. It is hoped that by presenting the concepts and techniques of interventional radiology as practiced at the Massachusetts General Hospital and thus providing a state of the art reference manual, this book will serve as the foundation for future developments in this new and exciting field of medicine.

JUAN M. TAVERAS, M.D.
Radiologist-in-Chief at the
Massachusetts General Hospital
and Professor of Radiology,
Harvard Medical School

INTERVENTIONAL RADIOLOGY
A Surgeon's Point of View

One of the most exciting and rapidly changing areas of medicine in the last two decades has been the field of interventional radiology. It includes radiologic methods that offer therapeutic alternatives to other modes of therapy (usually surgical) and/or methods that provide tissue diagnosis, usually involving percutaneous techniques. The rapid developments in this area have been due to many innovative accomplishments. In the 1960's, image intensification became available and resulted in improved precision and an increased ability to perform complex procedures. There was no longer a need to examine patients fluoroscopically in darkened rooms, and thus it was possible to perform radiologic procedures safely on patients who were quite ill. Following the introduction of percutaneous techniques, redesigned vascular catheters resulted in improved arteriography and the development of intraarterial treatment such as embolization and/or infusion of vasoconstrictor substances. In the 1970's modern ultrasound techniques and CT scanners were introduced, ushering in a new era in which lesions could be precisely defined using noninvasive techniques. Many other milestones of progress have occurred during the last 20 years and have resulted in the present state of interventional radiology.

In the practice of medicine, of course, one should always seek new and better ways to approach problems. Interventional radiology is a superb example of this quest. It is important to point out that this discipline requires considerable resources as well as radiologists with proper experience, most importantly, radiologists who are interested in participating in a personal patient-physician relationship—at any time of day or night—to deliver the best possible care.

The approaches discussed in this book are not meant to represent the only methods available for solving a particular problem. They are presented, as they should be, as possible alternatives in treatment or diagnosis. The authors are careful to point out that these procedures should not compete with surgical interventions but rather should serve to facilitate diagnosis and therapy, often in conjunction with surgery. The authors further emphasize that decisions about performing these procedures are best reached through consultations among the patient's primary physician, the patient's surgeon, and the radiologist. Clearly, a spirit of cooperation must exist among the various specialties involved in the care of a particular patient so that the most appropriate procedure will be chosen for each individual, the timing of the procedure will be ideal, and the maximum therapeutic impact and amount of information will be derived. This spirit of cooperation between radiology, surgery, and the other medical disciplines has been one of the hallmarks of the MGH interventional radiology program.

W. Gerald Austen, M.D.
Edward D. Churchill Professor of Surgery,
Harvard Medical School,
and Chief of Surgical Services at the
Massachusetts General Hospital

Because our intention here is to provide information on the "state of the art" of interventional radiology, emphasis has been placed on methodology—the equipment and materials needed for each procedure along with "step-by-step" instructions regarding technique. However, the scope of the book goes beyond merely a "cookbook" approach to each procedure. Indications and contraindications, clinical applications, and results as well as complications and ways to prevent them are appropriately discussed. At the end of each chapter, there is an overview focusing on the highlights of particular methods or procedures as well as possible future developments.

In all interventions, there is more than one way to achieve a desired result; the "best method" is only a relative term indicating the most appropriate procedure to solve a problem in an individual patient. Based on experience, the radiologist eventually chooses that procedure or technique which he or she can perform most effectively, and this explains the approach taken in this book. Rather than listing in great length and detail the entire spectrum of radiologic interventions, we have presented the one or two methods that we have found to be most successful in our hands. Therefore, the methodologies described here largely reflect current practice at the Massachusetts General Hospital.

We hope that this text will prove a useful companion and a handy reference to radiologists who are already expert interventionists as well as to those about to enter the field. For radiology residents and fellows in training, the book should provide a basic foundation on which they can build. For physicians and specialists in the medical disciplines, *Interventional Radiology* should provide information about when to consult with the radiologist in selecting the most appropriate procedure. Last but not least, for our surgical colleagues, this textbook provides details about radiologic interventions that may complement, facilitate, or at times replace a surgical procedure.

Christos A. Athanasoulis, M.D.
Richard C. Pfister, M.D.
Reginald E. Greene, M.D.
Glenn H. Roberson, M.D.

EQUIPMENT, MATERIALS, AND METHODS

chapter 1

Therapeutic Angiography: Its Scope and Basic Principles

CHRISTOS A. ATHANASOULIS, M.D.

THE SCOPE OF ANGIOGRAPHY

PRE-ANGIOGRAPHY CONSULTATION AND INFORMED CONSENT

THE ANGIOGRAPHY TEAM

POST-ANGIOGRAPHY VISITS AND FOLLOW-UP

THE SCOPE OF ANGIOGRAPHY

In the evaluation of diseases that primarily affect the blood vessels, angiography has been and continues to be an important diagnostic study. It is essential in the diagnosis of arterial obstruction due to atherosclerosis obliterans, aneurysms, embolism, thrombosis, dissection, or other vascular lesions. Although noninvasive hemodynamic tests provide functional data that can be used to amplify and enhance angiographic findings, angiography itself provides the specific morphologic information that allows optimal planning of an operative intervention. For other disease entities such as neoplastic and inflammatory mass lesions, the more recent techniques of ultrasound and computed tomography now constitute the "first line" of imaging tests, and diagnostic angiography is of less importance. In these cases, angiography is performed only when the results of ultrasound and computed tomography are equivocal or when it is necessary to delineate the vascular anatomy of a lesion or an organ prior to operation.

The introduction of therapeutic procedures represents a major change in the scope of angiography. Since angiographic methods can be used to increase or decrease regional blood flow, they can be effective in the treatment of vascular diseases.[1] The concept of therapeutic angiography is still new, and the following reports represent milestones in its early development (Table 1–1):

— Radiographic demonstration in 1959 by Rastelli et al. of contrast extravasation during experimental active gastrointestinal bleeding.[2]

— Artificial embolization of a cerebral arteriovenous malformation by Lussenhop and Spence in 1960.[3]

— Report by Margulis et al. of the application of intraoperative mesenteric arteriography to show cecal arteriovenous malformation.[4]

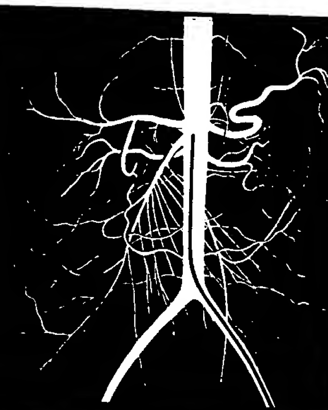
— Description in 1963 by Nusbaum and Baum of percutaneous angiographic techniques for demonstration of unknown sites of gastrointestinal bleeding.[5] This was the first step toward the application of angiographic methods for the control of bleeding and other therapeutic interventions.

— Introduction in 1964 by Dotter and Judkins of a new catheter technique "for percutaneous transluminal treatment of arteriosclerotic obstructions."[6]

than any signed form, however, is a full explanation by the radiologist, with sympathy and candor, of the planned procedure, its benefits and risks, and the possible alternatives. A brief, hurried visit with the patient is often counterproductive. Instead, the radiologist should take time to sit down and converse with the patient. During these discussions, the reassuring presence of a member of the patient's family should be encouraged. In conjunction with the explanation by the radiologist, the patient may be given a booklet that describes in general terms what angiography is all about (Fig. 1–2). To complement the basic information

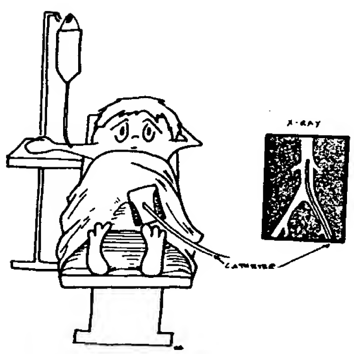
THE PATIENT'S GUIDE TO ANGIOGRAPHY

DEPT. OF RADIOLOGY – MGH



Dear MGH Patient

In a day or so you will be having a test called Angiography — a special x-ray examination for gaining information about your blood vessels and circulation. There are many reasons for this examination, and your doctor has probably explained to you its importance in the evaluation of your particular problem. This booklet was written to give you some information about the procedure and to answer questions that patients commonly ask.



What is Angiography?

Angiography is a special x-ray procedure for the study of blood vessels.

A plain x-ray, like that of your hand or your leg, shows the shadows of your bones. In order to see your blood vessels, contrast media (a radiopaque dye) must be injected into your blood stream while rapid x-rays are taken. This is Angiography, or you may hear people referring to it as an angiogram. An arteriogram involves the study of the arteries. A venogram is the study of the veins.

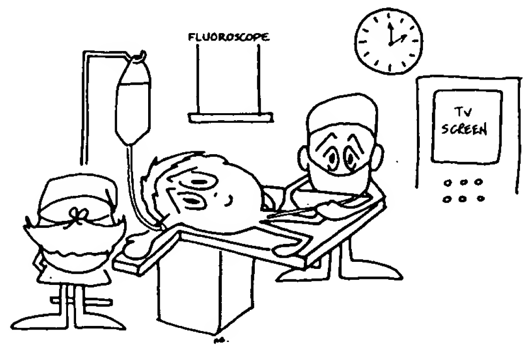
What is the Preparation for this Test?

After midnight, the night before your procedure, you should not eat any solid foods. It is very important, however, that you drink plenty of fluids both before and after your angiogram. Fluids are necessary because the contrast media or "dye" used in the test causes an increase in the amount of urine (you will be voiding more) and this fluid should be replaced.

Figure 1–2. Booklet used at the Massachusetts General Hospital to inform patients about the nature and risks of angiography.

You will be able to have all your regular medications. Before your angiogram you may receive medications ordered by the radiologist to help you relax and feel comfortable during the procedure.

The test is carried out in a special x-ray room in the Radiology Department on Gray 2. The procedure is usually performed from the groin. If another site is selected, the angiographer will discuss this with you. Shaving or clipping hair in the groin area is necessary. Shaving is important in order to remove hair on which bacteria may grow, and thereby reducing the possibility of local infection. This will be done when you arrive at the Radiology Department. The area will be cleansed carefully and draped with sterile towels. Then, an intravenous will be started to provide you with fluids during the examination.



What does the Procedure Involve?

Angiography is carried out by trained radiologists, technologists and nurses. They perform this procedure many times a day as a full-time occupation. The physicians will be wearing a sterile gown, cap and mask. During the test they will talk among themselves and to you. You should not mistake their routine discussion as an indication that problems have arisen.

During the test you will lie on a padded table which can be moved in all directions. Mounted above this table is an overhead fluoroscope (a kind of x-ray machine). The procedure itself involves passing a small, flexible, sterilized hollow tube (called a catheter) into an artery or vein. Through this tube contrast can be injected so that x-ray pictures of specific parts of your circulation can be taken. The catheter is guided to the various vessels by observing it through the fluoroscope. The room may be darkened at times during the procedure in order to facilitate seeing the catheter in the vessels. The fluoroscopic image of blood vessels and the catheter is displayed on a television screen which you may watch if you wish. The movement of the contrast is also recorded on x-ray film. The film, once developed, permits a detailed evaluation of the area examined.

When the contrast is injected you may feel a hot, flushed feeling. This is normal and it passes in a few seconds. You may be asked to take deep breaths or hold your breath and keep perfectly still while the x-rays are taken. At this time you should also expect to hear several noises around you made by the x-ray machines.

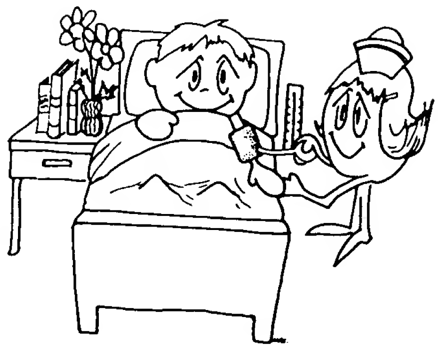
Your active participation and cooperation can be of great help. The radiologist performing the study will be keeping you informed as to the progress of the procedure.

Is the Test Painful?

The major discomfort entailed in the test is that you must lie fairly still for a period of one to two hours. Your back and limbs may become a bit stiff during this time. The length of the test will depend on the amount of information needed; however, a lengthy test is not a sign of seriousness of your condition. The catheter itself seldom causes any discomfort in any part of the body. Local anesthesia is all that is required. The blood vessels themselves are generally insensitive to the touch of the catheter. If you should have discomfort, please let the doctors know so that you can be given more local anesthesia or a pain reliever.

Figure 1–2. *Continued*

contained in the b oklet, details of the specific therapeutic procedure to be performed should be explained during the meeting and the patient's questions should be answered in order to establish a valuable feeling of rapport and trust between the patient and the radiologist. If possible, the procedure can also be explained as it is being carried out, to inform the patient prior to each step about what is to follow and what he or she is about to feel. In interviews with hundreds of patients who have undergone angiographic procedures, we have found that all patients agree that an ongoing explanation of events during the angiographic procedure allowed them to anticipate each step and was the single most important factor in reassuring patients and improving their tolerance during difficult or lengthy procedures.



What Happens after the Test?

After the test, the catheter will be removed and the radiologist will apply gentle pressure for 10-15 minutes to control any bleeding at the site of introduction. You will return to your room where you will be able to resume your regular diet. Back on the floor the nurse will check your blood pressure, inspect the puncture site, and feel for pulses frequently. You must remain in bed with your leg straight for 6-8 hours. You may experience a little soreness but medication can be ordered for discomfort after the procedure, so please ask the nurse for it if you are uncomfortable.

What are the Risks?

People often ask if the examination is dangerous. Any special diagnostic test involving the blood vessels may be attended by sudden and unusual reactions. However, such reactions are uncommon. Angiography has been in use for about twenty years, and long experience has taught the doctors performing it what the problems may be. Every safeguard is provided for the patient undergoing the procedure.

Many conditions for which angiography is used as a diagnostic measure have surgical implications. In these cases performing surgery without the information gained from angiography would be much more dangerous than avoiding the procedure because of the associated risks. The doctors carrying out the test are experienced and you can be sure that you are in good hands with them.

What about Exposure to X-Rays?

A great part of the radiologist's training is in radiation protection. During the procedure he or she will make sure that the necessary information is obtained with the minimal amount of x-rays. These are safe and there is no need for any type of protection or for concern on your part. The doctors and technologists involved in the test wear lead aprons, because they work with x-rays all day, every day.

Conclusion

Now that you have read this pamphlet, we urge you to discuss it and any questions you may have with your doctors and nurses. We anticipate that you may have individual concerns which cannot be answered here. One of the radiologists who will be doing your test will see you the night before and will answer any questions that this booklet may still leave in your mind.

He or she will also visit you in the afternoon or later during the day after the study to make sure that you are comfortable. It is our desire and expectation that you will have a smooth, uneventful test with minimal discomfort.

Prepared by
Ellen Johnson Carabello, R.N. and Christos A. Athanasoulis, M.D.
Illustrations by
Harriet R. Greenfield.

We wish to thank
Peter Yurchak, M.D. and the M.G.H. Cardiac Unit
for their help in the preparation of this booklet.

Figure 1–2. *Continued*

THE ANGIOGRAPHY TEAM

Therapeutic angiographic procedures are of varied complexity. Difficult, delicate procedures such as embolization of intracranial or spinal cord lesions should be performed only in tertiary care centers. More simple procedures can be performed in both the academic center and the community hospital, provided that the radiologist is adept in their performance and that equipment is adequate. (For a discussion of radiologic equipment and life-support systems in the angiography room, the reader is referred to Chapter 2.)

It is important to point out that complex therapeutic angiographic procedures cannot be performed by the radiologist alone but with the assistance of an "angiography team," which comprises the radiologist and his or her assistant (a resident or fellow in training), a

chapter 2

Imaging and Life-Support Systems in the Angiography Suite

ALAN J. GREENFIELD, M.D.

This chapter deals with issues important to the safe, rapid, and accurate performance of therapeutic vascular radiologic procedures. An attempt will be made to delineate those items essential to the performance of therapeutic angiography as well as other desirable and optional items that may be considered in the design or redesign of a special procedures facility. Obviously the vascular radiologic procedures described in this section of the text may be performed in hospitals in which the use of angiography varies widely—ranging from a few angiographic procedures per week to as many as 20 per day! At times, a life-threatening emergency will necessitate intervention even though the equipment available is less than ideal; meeting the needs of the patient must remain the first priority.

This chapter is not intended to set absolute standards but rather to serve as a guide. Those seeking a more detailed treatment of radiographic equipment are referred to a recent monograph by Thompson.[1]

IMAGING SYSTEMS

High-capacity generators and radiographic tubes are important in serial angiography to achieve exposure times that are short enough to eliminate motion, while maintaining subject contrast with techniques using high milliampere-seconds (mAs) and low kilovoltage (kVp). This requirement becomes even more important when therapeutic procedures involve critically ill patients, who are often unable to cooperate owing to pain or altered states of consciousness. Radiographic tubes with 100-kilowatt load capacity on the large focal spot and generators capable of supplying 100 kilowatts of power (1000 mA/0.1 second at 100 kVp) are recommended. This requires the use of high-speed rotating anodes (10,000 rpm). A focal spot of 1.3 mm with a 12-degree anode angle will cover a 14-inch field at 40-42″ SID.

Screen-film combinations should be chosen so as to enhance the capacity of the radiographic equipment. We use rare earth screens with a relative speed of 400 and films with appropriate spectral sensitivity (Kodak Lanex Screens and Ortho G film, with a developer temperature of 98° F). Also available is an 800-speed system using film that is twice as fast. With these combinations we are able to image the abdomen of adult patients with average radiographic factors of 40 to 50 mAs and 65 to 75 kVp.

When possible, serial film changers should be of the 14 by 14-inch cut film type. Roll film changers are reliable but are much more cumbersome to use. Biplane capability, although necessary in vascular radiology, is not of great importance for therapeutic procedures.

A high-resolution image amplifier and television chain with magnification fluoroscopy are necessary to enhance the radiologist's ability to visualize and cathe-

terize small arterial branches. Multiplane fluoroscopy, which may be achieved with either C-arm or U-arm equipment; a rotating cradle; or multiple-image amplifier systems are useful in increasing the accuracy of vessel selection. Especially in catheterization of the visceral vessels, a rotating cradle allows rapid visualization of the anterior branches of the aorta in continuously variable planes that are easily controlled by the fluoroscopist.

A rapid filming device that is not cumbersome to set up, such as a spot-film device or photofluoroscopic camera (105 mm roll film or 100 mm cut film), greatly simplifies documentation of catheter position and identification of catheterized vessels prior to vascular occlusive or infusion procedures. Videotape or disc recording is likewise useful for rapid playback of dynamic data for help in identifying vascular landmarks. It is also an alternative to cineangiography, when high speed is not the primary consideration (Fig. 2-1).

Sterilizable control handles allow the operator greater flexibility in positioning both the patient and the imaging equipment, controlling collimation, and initiating rapid-sequence photofluoroscopy without the need for a technologist's assistance. When possible, interventional procedures should be performed in a dedicated special procedures room, with an image intensifier suspended from the ceiling, and an angiographic table with a four-way floating table top. A system such as this allows much more careful attention to asepsis — an especially important consideration in interventional procedures. The ability to control room lights from the table is also useful.

PHYSICAL DESIGN OF THE SPECIAL PROCEDURES SUITE

Adequate space must be available, especially for the care of critically ill patients. Sufficient floor space to accommodate ventilators, suction bottles, and transducers as well as adequate passageways to allow transport of patients in hospital beds rather than on stretchers is advisable. Storage space for catheters, guidewires, intravenous fluids, dressing materials, and emergency supplies should be provided near the special procedures suite.

There must also be an adequate power supply as well as a number of wall outlets to provide for additional equipment that may be necessary. The operating suite at the Massachusetts General Hospital is equipped with explosion-proof wall plugs to allow use of operating room equipment in the radiology area without the need for adapter plugs. Essential equipment and wall outlets should be connected to the hospital emergency power system. Adequate heating, ventilation, and air conditioning equipment are necessary for both operator comfort and patient safety.

Several types of interventional procedures require surgical preparation, such as the introduction of vena cava filters or the implantation of chemotherapeutic infusion pumps, and therefore space should be allotted for the scrub nurse, instrument table, and electrosurgical apparatus.

Since it is necessary to maintain sterile technique during interventional procedures, especially embolization, surgical scrub sinks and a dressing room for personnel should be provided. Also, the special proce-

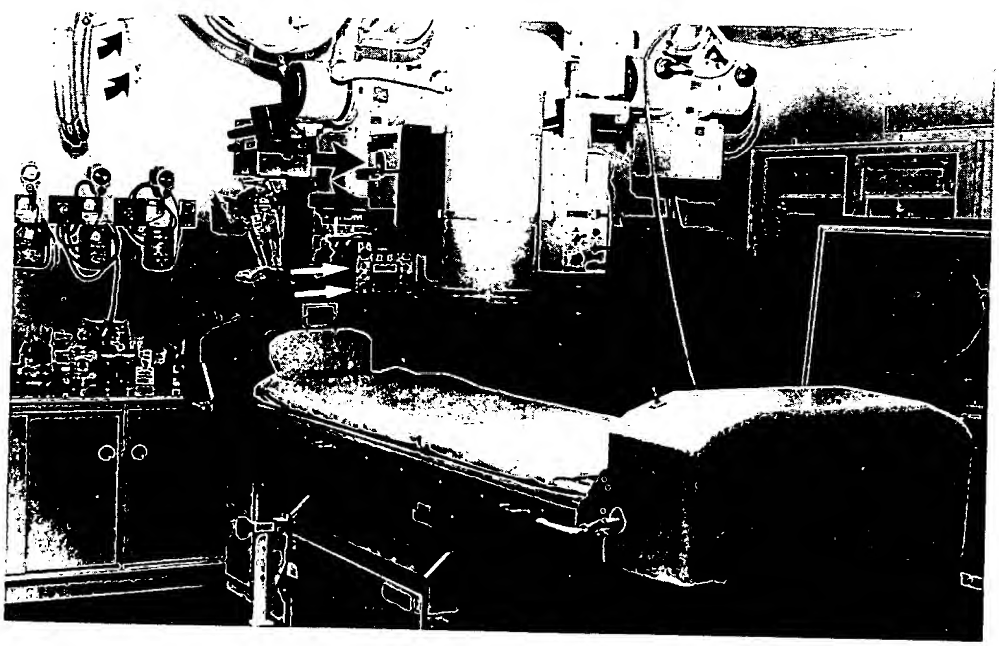


Figure 2–1. Special procedures suite for therapeutic angiography. The rotating cradle facilitates visualization of the visceral vessels in profile. The 105-mm camera (large black arrows) is particularly valuable for documenting catheter positions and for rapid visualization of vessels, eliminating the time-consuming process of setting up the film changer. A multichannel physiologic monitor (white arrows) is valuable both for intensive care of critically ill patients and for physiologic documentation of the results of angioplasty. The use of overhead-mounted hangers for IV equipment (curved arrows) increases available floor space.

chapter 3

Catheter Systems Used in Therapeutic Angiography and Methods of Superselective Vessel Catheterization

ARTHUR C. WALTMAN, M.D.

The purpose of this chapter is to present some guidelines for the selection of catheters, catheter systems, and wires used in therapeutic angiography. The discussion is based on our own preferences and the results of personal experience. The aim is not to present a primer on angiographic techniques. Rather, it is assumed that the reader is already familiar with the basic angiographic methods of vessel catheterization.

The question is often posed as to which catheter or guidewire is best to use in a given situation. Those vascular radiologists with long experience realize that no single catheter technique or catheter system can solve all problems. Rather, the angiographer should be prepared to adapt materials, catheter curves, and guidewires to accommodate the vascular anatomy of the individual patient. From a practical standpoint, this means that a large inventory of catheters and guidewires should be at hand. We encourage accumulation of a wide selection of catheters and guidewires and familiarity with their use (Tables 3–1 and 3–2).

The golden rule in selective and superselective vessel catheterization is that if a particular catheter configuration or a particular catheterization technique does not work, a different catheter curve or catheter system and a different approach should be used. It is better to stop briefly and reflect on and analyze the reasons for an inability to catheterize a vessel rather than to continue unsuccessful efforts using the same catheters for a long period of time. Of course consultation with other vascular radiologists or colleagues who may be available is always beneficial.

Another rule for successful superselective vessel catheterization is an understanding and visualization of the particular vascular bed which the angiographer is attempting to reach. Thus, fluoroscopic systems with good resolution, the use of video playback, the ability to alter the patient's position by means of a fluoroscopic cradle, and fluoroscopic magnification are all essential in defining precise vascular anatomy.

CATHETER SYSTEMS AND EQUIPMENT

GUIDEWIRES FOR VESSEL SELECTION (Table 3–1)

Guidewires in a wide range of diameters, shapes, and mandrel configurations should be available, even for simple angiographic procedures. For example, the

diameter wires are, unfortunately, too stiff for safe arterial manipulation. The smaller, 0.025-inch versions are quite useful. (See later discussion of Coaxial Catheter Systems.)

Because of the construction of safety guides, a solder point exists at the tip of a wire that is less flexible than the proximal wire core. As the wire exits from the catheter tip, it may injure the vascular wall. To prevent this, the catheter should be withdrawn slightly (2 to 3 mm) as the wire is introduced through the catheter tip. This may be considered an exchange of the guidewire for the catheter tip, and it is frequently useful.

We have attempted to standardize our equipment to some extent by trying to have two complete guidewire systems, one 0.038-inch and one 0.025-inch. However, we are forced to maintain materials of different diameters as well because of the limitations of manufacturing at these diameters. Some smaller-sized guides are kept on hand for pediatric catheterization, and 0.035 guidewires are necessary for some dilatation catheters.

All our guides are Teflon-coated to facilitate their movement within catheters that may contain multiple curves. The need for benzalkonium heparin coating of guidewires is uncertain but is worth the additional expense if embolic complications can be prevented while working near or in the coronary or brachiocephalic arteries.

As a matter of choice and to reduce the potential of mechanical failure, we do not reuse guidewires except under the most extreme circumstances, such as when wires are costly or are difficult to obtain from manufacturers.

CATHETERS (Table 3–2)

Originally, we shaped and tapered catheters to meet individual specifications, but we have found that the commercially manufactured catheters are of a higher quality than our own handmade versions. In addition, the wide range of materials for catheter production has limited the capability of duplicating some curves in one's own laboratory. Size, shape, tip, and wall performance of a standardized quality are crucial if coaxial systems are to be used or if rigid embolic materials are to be introduced.

As with guides, we do not reuse catheters because of structure and surface changes that render them fragile and more thrombogenic. We reuse only expensive catheters or those not readily available from the manufacturer.

INTRODUCING SHEATHS

Introducing sheaths are useful when multiple catheter exchanges are needed or when there is scarring about the groin. Sheaths should be self-sealing to prevent the leakage of blood.

COAXIAL CATHETER SYSTEMS

For catheterization of small branch vessels or for injection of plastic polymers, we utilize a coaxial system (Fig. 3–1) that accepts catheter tips tapered over 0.038-inch guidewires. The inner coaxial catheter is No. 3 French Teflon tubing without a terminal taper that accepts a 0.025-inch guidewire. This inner catheter is introduced through commercially available polyethylene No. 6.5 French catheters. The wall thickness is not great enough to impart sufficient radiopacity during abdominal fluoroscopy. To introduce the catheter, a Y-adapter is sufficient to maintain a fluid seal and allow irrigation between the catheters. The use of guidewires is mandatory, especially during introduction, since the thin-walled inner catheter may kink even within the primary catheter. The guidewire is used to identify the catheter position. The use of curved guidewires, deflecting wires, or preshaped biliary wires and gentle advancement and rotation of the catheter facilitate branch artery selection. Guidewires positioned beyond the catheter and catheter advancement over the wire constitute the preferred technique, but occasionally the entire system (catheter and wire) needs to be advanced as a unit; this is potentially traumatic, however. Although the inner catheter is small in caliber, contrast injections sufficient for fluoroscopic confirmation of position and diagnosis are possible in smaller vascular structures. Also liquid plastic polymers and pledgets of Gelfoam may be introduced via the inner catheter.

METHODS OF SUPERSELECTIVE CATHETERIZATION

NECK VESSELS

Selection of the thyrocervical and internal mammary arteries is required for ablation of parathyroid adenomas. The axillary approach offers a more direct and less complex means for catheterization of both these branches with a simple 90-degree catheter curve. This approach is reserved for patients in whom tortuous brachiocephalic vessels make catheter control difficult. Transfemoral selection of the internal mammary artery may be accomplished with a multiple-curve catheter (internal mammary catheter). Selection of the thyrocervical trunk is possible with head-hunter catheter curves, with the distal curve slightly accentuated.

In the internal mammary artery, the variable-stiffness guide is frequently helpful. If the branch artery selection is unsuccessful, utilization of a coaxial

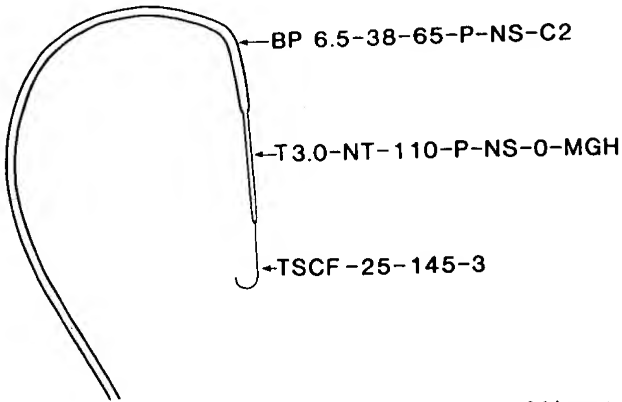


Figure 3–1. Coaxial catheter system. Components of this system consist of a selective catheter tapered to a 0.038-inch tip opening and No. 3 French Teflon tubing with no taper and designed to accept 0.025-inch guidewires (3-mm J is shown). (Available from Cook Co., Bloomington, Indiana.)

catheter system with soft and torque-controllable guides allows for precise small vessel catheter selection from both the femoral and the axillary approaches.

BRONCHIAL ARTERIES

Bronchial arteries may arise from the anterior aspect of the descending portion of the arch of the thoracic aorta or the lateral aspect of the thoracic aorta at the level of the carina. Most often a multipurpose catheter curve, often No. 5.5 French, is successful in selection of these arteries. With ectatic aortas or in the descending portion of the arch, a sidewinder curve may be needed. Catheter selection of the bronchial vessels is difficult in normal lungs because the arteries are small. Coaxial catheter techniques are helpful for superselective or branch selection. This is necessary if occlusion of radiculomedullary branches to the spinal cord is to be avoided during bronchial artery embolization.

ABDOMINAL VISCERAL ARTERIES

Selection of the celiac axis and superior mesenteric arteries is not difficult. Occasionally, however, time may be wasted in trying to identify the anterior aspect of the aorta. This waste may be reduced by positioning the patient for a 30-degree left posterior oblique projection. For selection of these vessels, femorovisceral ("Cobra") curves are usually chosen. Some patients present problems because of narrowing of the origin of the celiac axis, the result of atherosclerosis or, more often, of ligamentous compression. This is recognized when it is not possible to advance the catheter over a guide that is placed well into the vessel or when there is a narrowing approximately 0.5 cm from the origin of the vessel. If selection of the vessel orifice or the proximal portion of the major branches is desired, sidewinder curves are very effective. However, sidewinder catheters make more distal selection of the peripheral and small branches difficult.

Loop Technique (Figs. 3–2 to 3–6)

We have found that stable and precise selection of the branches of the celiac axis is important for infusions and embolizations. A loop technique, originally described and utilized by us, has been quite effective. The object of this technique is to invert the preshaped, curved portion of the femorovisceral catheter in order to utilize its advantage in vessel selection as though the catheter were inserted from an axillary approach. This can be carried out without additional manipulation of the catheter by advancing the catheter into a long branch vessel of the aorta, i.e., the celiac axis and the splenic or hepatic artery, the superior mesenteric artery, or the contralateral iliac system, with the help of a guidewire (usually a tapered-core 0.038 inch) positioned well into the branch vessel. After an adequate length of catheter has been advanced (10 to 20 cm), the catheter often starts to buckle or bend within the aorta. If this fails to happen, withdrawal of the guide to the intraaortic portion of the catheter or use of a stiff wire will elicit this bending. In some patients, rotation as well as advancement of the catheter can be used to initiate this bend. As the catheter is advanced, the bend ascends in the aorta, and the catheter tip withdraws from its distal position and inverts. Pulling on the catheter at the groin will force the tip forward into the vessel to be selected or down the aorta. The snug fit of the redundant loop within the aortic walls keeps the tip stable and increases the forward force on the tip. It is advisable to form this loop in the celiac axis for selection of the left gastric artery and the hepatic or splenic artery. The catheter tip can be placed as far distal as the combination of guidewires and loop allows. This combination can be most helpful in selection of the celiac axis when ligamentous compression interferes or when the axis has a cephalad course prior to branching. The technique for selecting the narrowed vessel origin consists of loop formation, usually in the iliac vessels, and advancement of the tip until it engages the origin of the celiac axis (Fig. 3–2). A straight, tapered-core wire is then introduced. The wire is advanced into the vessel, and the catheter is gently advanced over the wire while the tip is rotated slightly to conform to the course of the vessel.

When the loop is formed, the catheter tip points cephalad, and branches of the celiac axis, i.e., the left gastric or the inferior phrenic artery, can be identified by means of contrast injections. With rotation and advancement of the catheter, the tip will engage the origin of the vessel. If the distal loop curve is not tightly

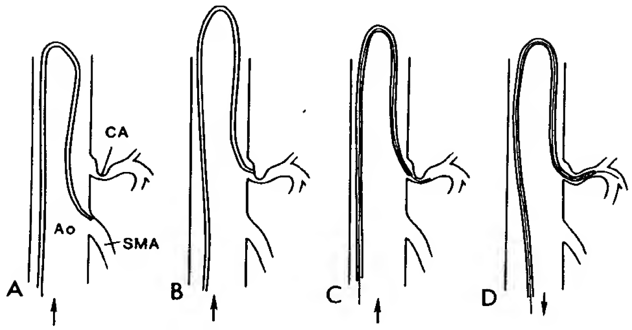


Figure 3–2. Catheterization of narrowed celiac axis (CA) by the loop method. After formation of the loop in a long branch of the abdominal aorta (Ao) (i.e., superior mesenteric artery [SMA] or contralateral iliac system), the catheter is advanced within the aorta until its tip engages the celiac axis (*A* and *B*). A straight, tapered-tip mandrel guidewire (LLT) is advanced through the tip of the catheter into the celiac axis (*C*). The catheter tip is advanced either over the guidewire or with the guidewire leading into celiac axis beyond the point of narrowing (*D*).

angulated, a tight, movable-core, 3-mm J guide may engage the origin of the vessel and facilitate catheter placement. When this occurs, gentle withdrawal of the catheter at the femoral artery will advance the tip well into the vessel.

Selection of the branches of the proximal superior mesenteric artery is also possible using the loop (e.g., hepatic arteries arising from the superior mesenteric artery and the inferior pancreaticoduodenal artery). Advancement of catheters distally into the superior mesenteric artery may result in arterial injury and should be performed with care. We have identified three patients in whom probable mesenteric vascular injury has occurred from vigorous loop formation in the superior mesenteric artery. Injury was manifested as an ecchymotic area in the mesentery in two patients and as an ischemic injury involving a small (5-cm) segment of ileum in another.

Manipulation of the catheter loop requires careful monitoring with fluoroscopy to avoid knot formation or braiding (tight winding) of the catheter. In our experience, knots have formed in three instances, but the careful use of guidewires and advancement of the catheter into the wider descending thoracic aorta permitted loosening of the knot and catheter removal.

The loop technique allows for multiple selection of vessels with a single catheter, and it avoids multiple catheter exchanges. The length of 65 cm is generally inadequate, so that catheters 75 or 80 cm long are recommended.

LEFT GASTRIC ARTERY
(Figs. 3-3 and 3-4)

Selection of the left gastric artery is difficult and frequently unsuccessful with most techniques. The loop method described above has been used by us and others and has proved successful in 90 per cent of attempted catheterizations. If the celiac axis can be easily catheterized, the loop is formed in the hepatic or splenic artery (Fig. 3–3). After the loop is formed and the catheter tip inverted, the tip is withdrawn to the celiac bifurcation. Rotation of the patient into a left posterior oblique position allows test injections to identify the course of the celiac axis and its branches and their anterior-posterior relationships. With rotation, withdrawal, and advancement of the catheter tip, the origin of the left gastric artery is often engaged. Further gentle removal of the catheter at the femoral site will advance the catheter tip into the left gastric artery. In some patients the tip does not easily enter the left gastric artery, and the use of a tapered-core straight wire may be necessary. In other patients the catheter tip does not have sufficient angulation to engage the origin of the vessel; placement of a 3-mm J-wire tip just beyond the catheter tip helps to engage the artery origin; catheter advancement with the guide leading may be successful. If the celiac axis cannot be easily catheterized with a simple catheter curve, the loop can be formed in the superior mesenteric artery or contralateral iliac artery, as described above (Fig. 3–4).

During attempts at left gastric artery catheterization it should be remembered that the artery may originate from the aorta and that it may have a combined origin with either one or both inferior phrenic arteries. In the latter instance, the loop technique is helpful in order to advance the catheter tip into the left gastric artery beyond the orifice of the inferior phrenic artery (see also Chapter 6).

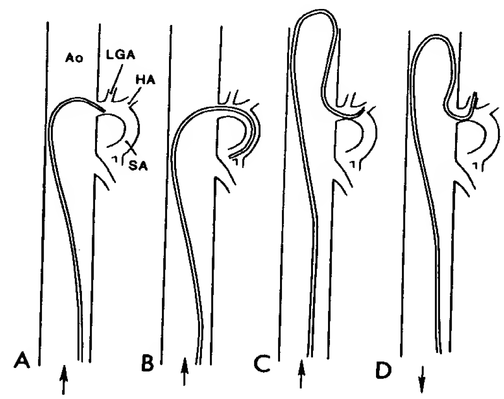


Figure 3–3. Left gastric artery (LGA) catheterization by loop method, with the loop formed in the splenic artery. Formation of the loop within the celiac axis is preferred for left gastric artery selection (*A*). Selection of the celiac axis and one of its major branches, such as the splenic artery (SA) or hepatic artery (HA), is performed (*A* and *B*). The catheter is advanced until a knuckle is created within the abdominal aorta (Ao) and the catheter tip inverts and begins to withdraw. The catheter tip withdraws to the level of the celiac bifurcation as the catheter is advanced in the groin (*C*). After the catheter tip engages the origin of the left gastric artery, withdrawal from the femoral artery will advance the tip into the left gastric artery (*D*).

chapter 31

Percutaneous Interventional Uroradiologic Procedures: Principles and Experience

RICHARD C. PFISTER, M.D.,
JEFFREY H. NEWHOUSE, M.D.,
and
ISABEL C. YODER, M.D.

Interventional uroradiology may be defined as any percutaneous radiologic procedure that provides an anatomic, bacteriologic or tissue diagnosis, physiologic data, or a therapeutic alternative to conventional management. In the urinary tract, these procedures may be accomplished by the transcutaneous passage of a needle or catheter system into or around the kidney, ureter, or bladder.[1-9]

Other interventional techniques are performed via catheters in the vascular system, including renal artery angioplasty, tumor embolization, control of bleeding from the kidney or bladder, and lymph node biopsy following lymphangiography. These procedures are described in other sections of this book.

HISTORICAL BACKGROUND

Although many nonangiographic interventional procedures were initially described many years ago, they did not rapidly come into common usage. In 1970, we began to evaluate systematically the techniques originally described and their modifications. Further modifications have followed, and new methods, techniques, and equipment for their performance have evolved.

In our institution, diagnostic and therapeutic applications of percutaneous approaches to the urinary tract have been performed with the full cooperation and encouragement of our colleagues in urology and nephrology (Table 31–1).

TABLE 31-1. PERCUTANEOUS URORADIOLOGIC PROCEDURES

Diagnostic	Therapeutic
Cyst puncture	Cyst ablation (sclerosis)
Renal cyst	Drainage, retroperitoneal
Pseudocyst	Fluid collections
Deep pelvic cyst	Abscess
Biopsy	Urinoma
Aspiration (liquid, solid)	Lymphocele
Brush	Other
Endoscopy	Nephrostomy
Cystic cavity	External drainage
Pyelocalyceal	Fistula/leak
Antegrade pyelography	Stents
Ureteral perfusion	Dilatation of stenosis
Suprapubic cystourethrography	Stone displacement, extraction, and dissolution

METHODOLOGY

Instrumentation

Ideally, an absence of cutting edges is desirable for percutaneous needles, trocars, or other instruments; this is particularly so for those used in highly vascular organs such as the kidney (Fig. 31–1). The large single-bevel needles (14- to 18-gauge) have a sizable oval sharp edge; some trocar units have four beveled cutting edges at their points, and the potential for severe bleeding due to laceration or transection of an artery would seem considerable. For needles and trocars larger than 20-gauge, the smooth pencil point unit, which has a tip the size of a 22- to 23-gauge needle but is devoid of any cutting edges, seems advantageous; such designs can be combined with a recessed sidehole and hollow-bore central shaft, which provides for a fluid return upon successful entry into a fluid-filled cavity or organ.

Currently, needles, trocars, catheters, and other various devices desirable for many of the percutaneous uroradiologic procedures are not readily available, and one must search for, borrow, adapt, or at times even create the appropriate items.

Approaches

To approach the adrenal glands, kidneys, upper halves of the ureters, and their surrounding tissues, the translumbar method may be used. The ureter below the bony iliac crest, low ectopic kidneys, masses, nodes, and the bladder must be approached through the anterior abdominal wall. Entry into the bladder may still be extraperitoneal.[3]

All translumbar entry sites to the superior half of the upper urinary tract should be below the 12th rib. If an intercostal needle approach is used, a pneumothorax can be expected to occur in approximately 50 per cent of cases. To circumvent such complications, a skin entry 2 to 3 cm below the lowest rib should be chosen, and the needle is directed cephalad to reach the upper pole of high kidneys or the adrenal glands. The lateral approach is not used, since it involves greater risk of puncturing other abdominal viscera. The posterior-oblique exit of a catheter need not be uncomfortable if it is appropriately bandaged.[1-3, 8, 9]

Techniques

All percutaneous uroradiologic procedures begin with the use of a flexible 22-gauge needle. Short needles with 4-cm shafts are ideal for the newborn and infant. Medium-sized children and thin adults require an 8- and 10-cm shaft, while longer needles are required for the heavy adult or when the previously mentioned oblique subcostal approach is used. Such long, flexible needles must be carefully directed and advanced to avoid bending of the needle, with resultant malposition of the needle tip (Fig. 31–2); in many instances, a slightly stiffer 20-gauge needle is easier to control in the longer length.[1]

Although leaving a stylet within such flexible needles provides support, we have found that the aspiration technique with a syringe attached to the needle is advantageous to successful puncture. Fluid return through a thin needle depends upon intracavitary fluid pressure and fluid viscosity. If the length of the needle is greater than the amount of pressure, then fluid return cannot be spontaneous; aspiration with a small syringe (10 ml) attached to the needle permits retrieval of fluid in low-pressure systems or of viscous solutions. Such poorly flowing, thick liquids may be encountered if the lesion is hemorrhagic, necrotic, or purulent.

Another advantage of keeping the syringe, as opposed to the stylet, attached to the needle is the ability to use the same needle for anesthesia. By placing 5 to 6 ml of local anesthetic within the small syringe, one can advance the needle while continuously injecting small amounts of the anesthetic. In addition to providing anesthesia, injection prevents the lumen of the needle from plugging and, when combined with intermittent gentle aspiration, signals successful puncture by the return of fluid.[1]

When a catheter for nephrostomy or drainage of retroperitoneal fluid is to remain in place, passage of the needle or trocar should be as bloodless as possible. If frank blood is encountered, the instrument should be withdrawn, flushed with saline, and redirected to its final position. Poor healing of a vessel wall, especially in the presence of infected fluid, may result in prolonged bleeding either when the catheter is initially placed or when it is removed, discontinuing its tamponade effect.

Needle Guidance

Small, portable real-time sonography units may be useful for guiding the initial puncture, but it is essential that fluoroscopy be used to monitor injection of materials and catheter placement.[1-3] Although sonography is often able to demonstrate a catheter within a large fluid-containing structure, the tip of the catheter and its ability to drain a cavity completely and to be flushed without extravasation can only be demonstrated by fluoroscopy.

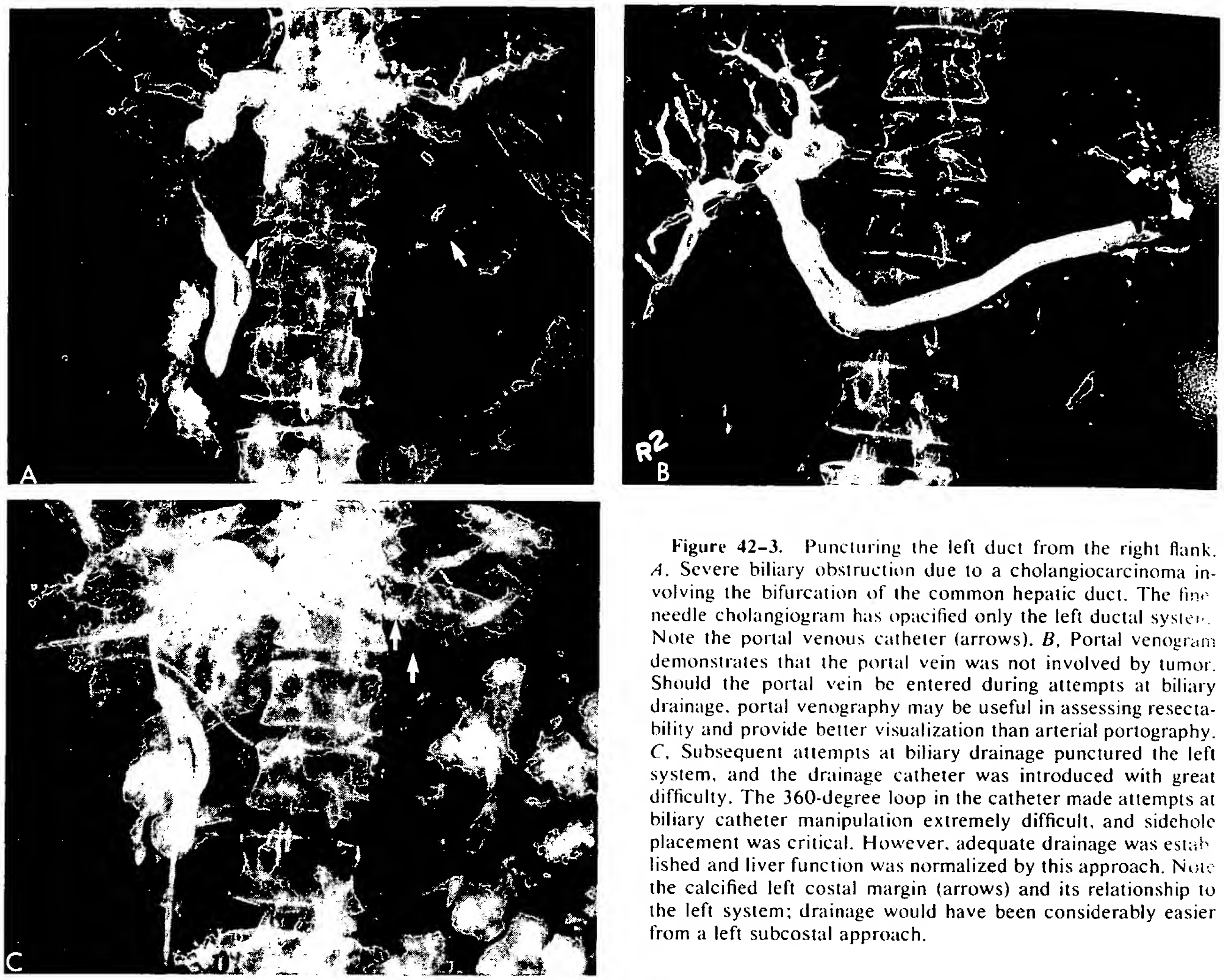


Figure 42–3. Puncturing the left duct from the right flank. *A*, Severe biliary obstruction due to a cholangiocarcinoma involving the bifurcation of the common hepatic duct. The fine needle cholangiogram has opacified only the left ductal system. Note the portal venous catheter (arrows). *B*, Portal venogram demonstrates that the portal vein was not involved by tumor. Should the portal vein be entered during attempts at biliary drainage, portal venography may be useful in assessing resectability and provide better visualization than arterial portography. *C*, Subsequent attempts at biliary drainage punctured the left system, and the drainage catheter was introduced with great difficulty. The 360-degree loop in the catheter made attempts at biliary catheter manipulation extremely difficult, and sidehole placement was critical. However, adequate drainage was established and liver function was normalized by this approach. Note the calcified left costal margin (arrows) and its relationship to the left system; drainage would have been considerably easier from a left subcostal approach.

avoided. If the angle is too acute, the catheter and wire manipulation and exchange will be very difficult. If the left ductal system is punctured from the right flank, a new attempt should be made to enter the right system; otherwise, the procedure will be much more difficult, and it may not be possible to place enough sideholes proximal to the obstructing lesion to provide adequate drainage (Fig. 42–3).

For a right-sided puncture, the main right hepatic duct, which runs cephalad and posteriorly, is usually chosen. A puncture site 1 to 2 cm posterior to the midaxillary line in the 11th interspace is usually appropriate, but should be modified to minimize the angle of puncture, as discussed above. For the left system, an anterior subcostal approach can be used, with the puncture made in the left-to-right direction.

Whenever possible, a peripheral puncture of the ductal system should be made. When puncture is made too centrally, it is often difficult to introduce sufficient numbers of sideholes above the obstructing lesion to ensure adequate drainage. In addition, tumor growth may further reduce the space available for proximal sideholes, requiring repuncture of the system.

Intubation of the Biliary Tree

The lateral radiograph and, occasionally, the left posterior oblique position are usually sufficient to guide the needle-catheter system to the desired segment of the biliary tree. Biplane fluoroscopy is cumbersome and is not generally useful, although it may have merit in difficult cases; its routine use should be avoided because of the radiation dose to the operator. The patient is asked to suspend respiration in midinspiration. The puncture is performed with a 30-cm, 19-gauge needle sheathed with an 18-gauge Teflon catheter tapered to an 0.038-inch wire guide. Puncture is performed under fluoroscopic guidance. Both the visible deformation of the duct and a palpable and visible "pop" will be observed when the chosen duct is crossed. The needle-catheter is advanced beyond the duct. When the liver is heavily infiltrated with tumor, puncture and catheter manipulation and exchange may be extremely difficult.

At this point, the needle is removed from the catheter, and a saline-filled syringe is attached. The catheter is withdrawn while gentle negative pressure is

maintained on the syringe. When bile flow is obtained, contrast is injected to confirm entry into the biliary tree. If blood is obtained, the catheter is withdrawn further until bile flow is present. If bile is not aspirated, the needle is reinserted and the system redirected; if possible, the catheter is not withdrawn from the liver capsule in order to avoid multiple punctures communicating with the peritoneal cavity.

Once free flow has been secured, and contrast injection has confirmed that the catheter tip is within a bile duct, a wire guide is introduced into the biliary duct. We have found that a 3-mm J shape is the best initial choice, choosing either a fixed or an LLT (Newton) core. If after entering the system the guidewire directs itself toward the liver hilum, the catheter is advanced over the wire and its intraluminal position is again confirmed by aspiration and contrast injection. If the guide chooses a retrograde course toward the periphery, a movable-core 3-mm J guide with the core removed for 25 to 30 cm can be introduced. The soft guidewire will buckle upon itself at the site of entry into the duct when the tip of the wire cannot advance any further toward the periphery, and the apex of the buckled segment will usually direct itself opposite the initial course of the wire and toward the liver hilum; the catheter can then be advanced over the wire in the correct direction (Fig. 42–4*A*). Alternatively, a directable guidewire such as the Eisenberg torque guide or the Lunderquist malleable-tip torque guide[14] can be used to direct the tip of the wire toward the liver hilum (Fig. 42–4*B*). The third approach involves exchanging the straight Teflon catheter for a curved visceral catheter, such as a cobra shape. If the guidewire chosen for this exchange cannot be advanced well into the biliary tree, a movable-core wire with the core minimally withdrawn should be chosen, so that the catheter will follow the guidewire (Fig. 42–4*C*).

If no guidewire will enter the biliary tree, a 3-mm J guidewire can be advanced 1 to 2 cm beyond the tip of the catheter, and the core can be withdrawn for a short distance. The wire will remain straight within the needle track in the liver. The catheter and guidewire are slowly withdrawn, and the tip of the guidewire is observed. The J configuration will re-form when the distal tip of the guidewire is withdrawn far enough to lie within the biliary radical. The guidewire is then advanced and the catheter is advanced over the guide (Fig. 42–5).

Once the catheter has been advanced to the site of the obstruction, a brief attempt is made to cross the obstruction. Should this attempt be successful in reaching the duodenum, exchange for the Ring drainage catheter[15] is performed. If not, the radiolucent Teflon sheath can be exchanged for a No. 6 or 7 French straight radiopaque polyethylene catheter with

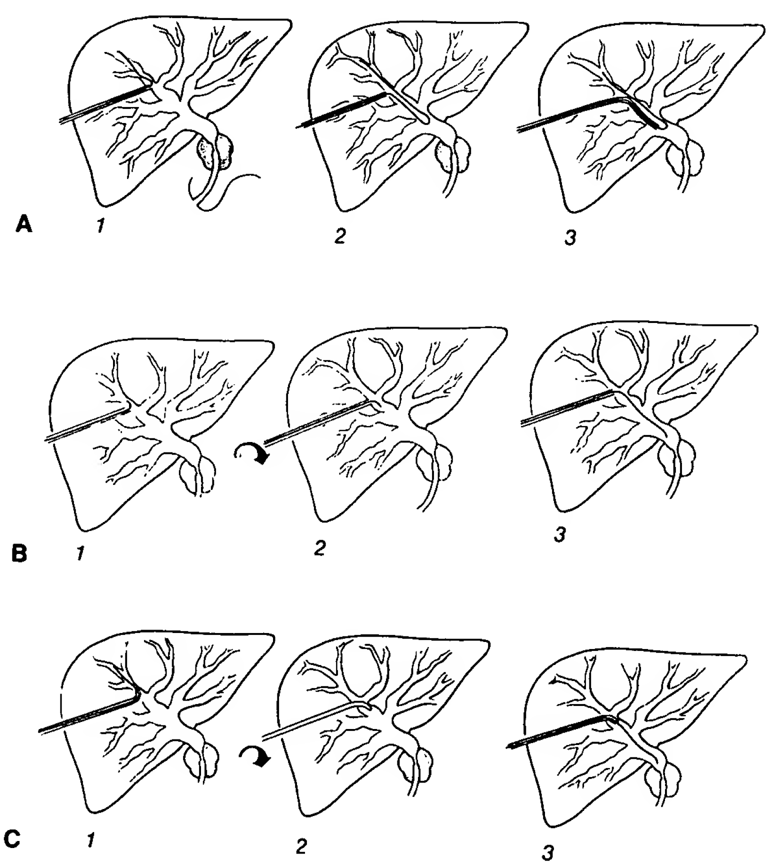


Figure 42–4. Methods for reversing direction when the guidewire will not advance toward the obstruction.

A, Use of a movable core wire. *(1)* A guidewire introduced through the catheter persistently advances toward the periphery, away from the obstructed segment. *(2)* A removable core guidewire is introduced, and the core is withdrawn from the wire as the wire is fed into the catheter. The soft, floppy guidewire will buckle when it can no longer advance toward the periphery and begins to advance toward the more central portion of the biliary system. *(3)* The catheter is then advanced over the guidewire, and the guidewire is withdrawn and redirected centrally.

B, Use of a Lunderquist wire. *(1)* The guidewire is introduced for a short distance to re-form the distal curve. *(2)* External torque placed on the guidewire directs the tip centrally. *(3)* The guidewire is advanced to the central confluence of ducts, and the catheter is advanced over it.

C, Use of a curved catheter. This approach is more likely to fail, since the catheter has a greater tendency to slip out of the punctured duct system. *(1)* The catheter is introduced over a guidewire placed as peripherally as possible into the system. *(2)* The catheter is rotated to direct it centrally. *(3)* The guidewire is advanced toward the site of obstruction.

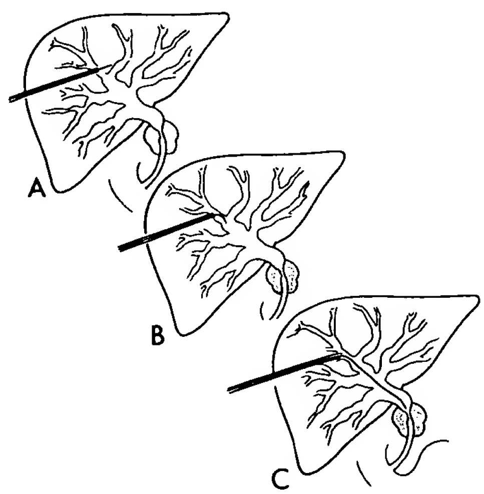


Figure 42–5. Entering the duct system after successful puncture has occurred. Occasionally, despite free flow of bile from the catheter, a guidewire introduced into the catheter will not enter the ductal system. Retraction of the catheter alone carries the risk of extraction from the punctured duct. The technique described here allows fluoroscopic detection of entry of the guidewire into the duct lumen. *A*, A 3-mm J guidewire (preferably LLT core) is extended beyond the catheter into the needle track in the liver. *B*, The catheter and guidewire are withdrawn very slowly under fluoroscopic observation, and withdrawal is terminated when the J configuration is seen to reconstitute. *C*, The guidewire is then advanced and enters the duct system successfully, allowing introduction of the catheter over the guidewire.

sideholes to simplify visualization of the catheter and allow contrast introduction while the wire guide remains in place or with the catheter tip obstructed.

Crossing the Obstruction

In most cases, the Lunderquist torque guide is employed for quick negotiation of the obstructed segment. A right-angle bend is made in the tip of the wire, and the site of obstruction is probed while the wire is rotated. Gentle forward pressure during rotation under fluoroscopic observation will, in most cases, advance the wire atraumatically through the obstruction. If initial attempts are unsuccessful, changing the tip angle or using a straight or 15-mm J guide is suggested. A curved catheter may successfully direct the wire tip toward the true lumen, especially when the obstruction is at a point of angulation of the duct or is eccentric (Fig. 42–6). Rotation of the patient or elevation of the head of the table may allow sufficient distal flow of contrast to demonstrate the true course of the ducts; often it will be seen that a tapered obstruction is a cul-de-sac and not the true course of the common duct.

If initial efforts at crossing the obstruction are unsuccessful, the straight catheter should be replaced with a pigtail catheter with an appropriate number of sideholes. If possible, the catheter should be advanced into the left hepatic duct to allow more sideholes to be placed within the liver. After 48 to 72 hours of external drainage, reopacification of the duct system often demonstrates a narrow lumen through the obstruction. Even if the path through the obstruction has not been demonstrated, crossing the obstruction should be attempted, since the edema and inflammation due to the elevated intraductal pressure and/or cholangitis are reduced after external drainage, and another blind attempt at crossing the obstruction will usually succeed.

Once the guidewire, followed by the catheter, has entered the duodenum, the Ring catheter is introduced. Exchange is often conveniently performed over the Lunderquist malleable guide. However, a

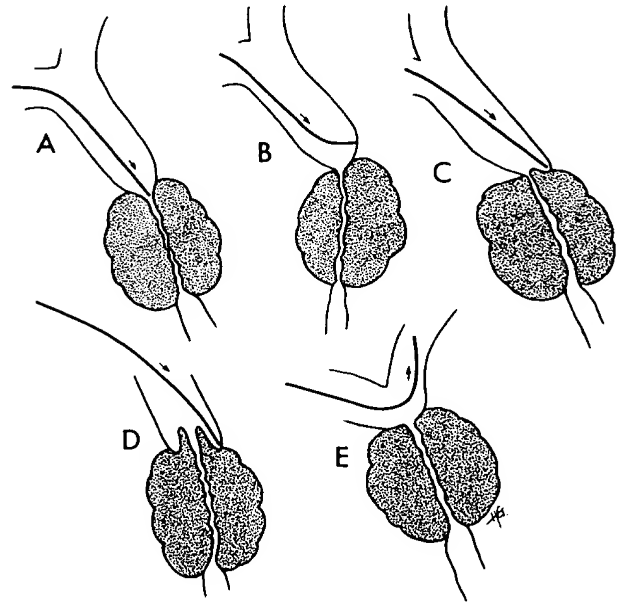


Figure 42–6. Methods for successful negotiation of obstructions. *A*, Most commonly, the lumen of the obstruction is relatively concentric relative to the dilated proximal duct system, and the wire will enter an obvious tapering segment of the duct system and traverse it upon rotatory motion of the Lunderquist wire. *B*, If obstruction fortuitously occurs at the point where the duct is angling posteriorly and caudad, the wire will tend to direct itself against the sidewall of the proximal duct rather than being directed toward the obstructed segment. Use of a curved catheter or an accentuated distal curve on the Lunderquist wire is often successful. *C*, A cul-de-sac lateral to the true lumen gives the appearance of a tapered segment entering the obstruction. Use of a tilt table or the left lateral decubitus position may allow the obstructed segment to fill sufficiently to reveal the true anatomy of the obstruction, which is then approached with appropriately angled wires or catheters. *D*, The obstructed portion of the duct is elevated by ingrowth of tumor into the duct so that the guidewires and catheters slip out of the lumen into recesses on either side. *E*, An obstruction just below the confluence of the right and left hepatic ducts is often the most difficult type of obstruction to deal with. All guidewires or catheters employed will preferentially enter the opposite duct rather than the obstructed segment that is more difficult to negotiate. Attempts after 48 hours of external drainage may be successful in this case, since the lumen of the obstruction may be slightly widened after external drainage.

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